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THE CONTROL OF APPLE SCAB.

By W. Goodwin, E. S. Salmon and W. M. Ware.

I.—ALLINGTON PIPPIN AND NEWTON WONDER.

In 1927, spraying experiments were carried out in one of the apple plantations at the South-Eastern Agricultural College, Wye, Kent, with the object of determining (a) whether the prevention of scab could satisfactorily be secured on Allington Pippin and Newton Wonder by spraying with ordinary Bordeaux mixture; and (b) whether a Bordeaux mixture made with ready-prepared slaked lime (i e. commercial hydrated lime or calcium hydrate) was equal in fungicidal power to the ordinary one in which lump quicklime is freshly slaked at the start.

The trees of Allington Pippin and Newton Wonder selected comprised the whole of a small plantation. They were half-standards (on Crab stocks) and had been planted in 1913, both varieties being at 28 feet square. The height of the Allington Pippin trees was 12-15 feet and their spread 21 feet; that of the Newton Wonder trees was 15 feet and their spread 24 feet. There were forty-two trees of the Newton variety and thirty-six of the Allington. The plots were arranged in such a way that three control blocks each consisting of nine trees left unsprayed, were distributed in different parts of the plantation. These plots, numbered 1, 2, and 3, included altogether twelve trees of Allington Pippin and fifteen of Newton Wonder. The remaining trees in the plantation were then divided into two plots: A, sprayed with hydrated lime Bordeaux mixture (twelve Allington Pippin and twelve Newton Wonder), and B, sprayed with ordinary Bordeaux mixture (twelve Allington Pippin and fifteen *Newton Wonder).

The main results of these experiments, which gave a very successful control of scab, are mentioned in the present article; for further details and for an account of the method of making the two types of Bordeaux mixture used, reference may be made to the *Journal of the Ministry of Agriculture*, XXXV, 226 (1928).

In 1928 the spraying experiments were continued on the same lines, using the same trees and the two types of Bordeaux mixture. The trees in plot A were sprayed with Bordeaux mixture made with hydrated lime† (8 lbs. copper sulphate, 12 lbs. hydrated lime, 100 gallons water). The trees in plot B were sprayed with ordinary Bordeaux mixture (formula 8-8-100), the quicklime being slaked just before use.

The first spraying took place on April 27th, 1928; a small hand-spraying machine, with two 60 ft. rubber leads and lances fitted with "Mistifier Junior" nozzles and smallest aperture discs, was used. One man worked the pump and maintained a pressure of 70-125 lbs. The weather was fine and sunny with a fresh wind which made the covering of one side of the trees somewhat difficult. The Allington trees were in the

* One Newton Wonder tree had recently been replaced by a small tree (about 6 ft. high) which was too young to bear more than a negligible crop.

† The hydrated lime used was a high-grade commercial brand containing 90-92 per cent. calcium hydrate and costing £2 10s. per ton f.o.r. in paper-lined bags.

" pink-bud " stage with here and there a flower in the truss wide open ; a considerable amount of leaf was now being produced, as many as seven leaves having expanded from the elongated wood-buds. Blossom was not plentiful. The Newtons were slightly more backward and no petals had opened. Here again there was a shortage of blossom and abundance of leafy wood-buds on the lower branches to half way up the tree.

Scab was not found on either variety in plots A or B, but in each of the three control plots, a single infected leaf of both varieties was found. The amount of Bordeaux mixture applied in the case of plot A was 35 gallons and plot B, 47 gallons, or about 1½ to 1¾ gallons per tree.

On May 19th, two days before the second spraying was carried out, the orchard was inspected. New wood on the Allingtons had grown to about 5½ inches in length and a few leaders had reached 7 inches. Of the eleven or twelve leaves on this new wood, only four or five were protected by the deposit of the first spray. In the infertile rosettes (*lambourdes*), about six of the seven or eight leaves were similarly protected. In both the plots, A and B, scab was rare, being only found here and there on the older leaves. One exception was seen on that side of a tree which, owing to the wind, had not been properly sprayed. A new shoot 5 inches long, showed scab on all its leaves (eleven in number) with the exception of the youngest two which were just unfolding. In the control plots, scab was immediately visible on approaching the Allington trees. The foliage on the new wood (5 to 6½ inches) was attacked and sometimes the smallest and youngest leaf was the only one of the eight to twelve which was not infected. It was common to find scab on the lower six leaves of such shoots. The fungus was present on the upper and lower surfaces of the leaves, in the form of spots, or spread along the mid-rib or veins. When it occurred on the lower surface, it caused very considerable puckering and a dark brown discoloration of the upper surface. In several cases all of the six or eight leaves forming the infertile rosettes (*lambourdes*) were badly scabbed and exhibited brown and dead areas. The curled leaves, many of which were dark-coloured with dead or dying areas, made the attack very noticeable.

As regards the variety Newton, which being short of blossom was producing abundance of foliage, the new wood had reached a length of 5½ inches with about ten leaves. In plots A and B, the Bordeaux deposit could be seen on the lowest three leaves ; the upper seven were unprotected yet quite free from scab. The disease in both these plots was very rare and on any Newton tree only one or two spots were found and these were on the small leaves surrounding the blossom trusses.

In the unsprayed (control) plots, the Newtons looked green and healthy and in view of the leafy condition of the trees, surprisingly few leaves were attacked ; those which were, however, bore large and vigorous spots (or larger areas) of the fungus which was in the fruiting condition. Some of the older leaves round the blossom-trusses showed a brownish coloration of the upper surface which was found to consist of comparatively large areas (¾ inch diameter) of the scab fungus in a sporing condition. The leaf tissues were often killed and the brown, dead areas showed on both surfaces ; when this attack took place near the margin, it resulted in contortion of the leaf-blade (lamina). Only one case was seen in which the leaves on the new wood were attacked. Ten leaves had expanded on a shoot 3½ inches long and only on the seventh leaf from the base was the fungus found in streaks extending along the veins of the upper surface. Somewhat worse attacks were found on the leaves of the infertile rosettes where spots of the fungus, up to half-an-inch in diameter, occurred on the lower surface, killing the leaf-tissues and causing brown areas to appear on the upper surface. On the largest of

these leaves (2½ inches long), scab occasionally was found following the course of the larger veins and extending over the whole upper surface of the lamina.

For the second spraying on May 21st, the weather conditions were favourable but again there was rather more wind than was desirable for good work. Plot A received 60 gallons of spray and Plot B 58 gallons, or about 2 to 2½ gallons per tree. The spray dried on well; no rain fell until ten hours later when wet weather continued for a period of twelve hours.

The plantation was again visited on June 18th as the trees were on that date about to be sprayed for the third time. The crop was light and the condition of both varieties, as regards growth and disease, was the same in plots A and B. On the Allingtons the new wood had grown to a maximum length of 14 inches, with sixteen leaves expanded. Of these, only the lower seven or eight were covered by Bordeaux deposit. There was very slight purple-spotting or coloration of the lower surface of some older leaves, though no serious injury—an appearance not seen on the unsprayed (control) trees. No scab could be found on any of the foliage. The largest apples had grown to a diameter of 1 inch and spots of the fungus up to one-tenth of an inch diameter were found on a very few of the fruits.

On the unsprayed (control) trees of Allington, the longest new wood had reached a length of 18 inches with sixteen or seventeen leaves expanded. Sometimes all of these leaves were attacked or more commonly all except the four or five on the upper part of the shoot. The state of these trees was very different from that of the sprayed trees in plots A and B; most of the foliage was blackened by the fungus; many leaves were puckered; brown, dry, crisp, dead areas on the leaves, due to the scab fungus, were everywhere conspicuous. Many of the apples—at a rough estimate about half of the crop—were spotted with scab; on the worst of these, the whole of one side of the apple was covered with small spots (each one-tenth of an inch diameter) which were then in process of coalescing.

As regards the Newtons in plots A and B, the fungus was present on very few leaves and the foliage was healthy and clean. The longest of the new shoots had reached a length of 9 inches on which about fourteen leaves had expanded. Of these, the lower seven or eight showed the protective deposit of Bordeaux Mixture. The fungus was occasionally found on the new shoots, sometimes occurring on the leaf next above the uppermost which had been sprayed. The scab on these unsprayed leaves formed spots (approximately ¼ inch diameter) or sometimes it spread over nearly the whole of the blade (lamina). There was slight purple spotting, probably due to the last spraying because it was not seen on the unsprayed trees, but this never amounted to serious injury. The apples (up to 1.1 inch in diameter) were clean, only one here and there being infected with minute spots of scab.

The foliage of the unsprayed Newton trees in the control plots was darkened by the scab fungus and the surface of some leaves was completely covered. Of the thirteen leaves counted on the longest new shoots (10 inches long) it was common to find all but two or three affected. The apples were very generally spotted.

The third and final spraying which took place on that day (June 18th) was much lighter than the two previous ones; 24 gallons of spray were applied to plot A and 26 gallons to plot B, or about 1 gallon per tree. The weather was dull and the wind light. Rain fell two-and-three-quarter hours after the spraying was finished and became heavier later. On the following day the Bordeaux deposit was seen to be adhering satisfactorily.

Two months later, on August 17th, the plantation was visited and it was again found that no perceptible difference existed between the trees situated in the two sprayed plots. The foliage of the Allingtons (except on one or two trees where " Red Spider " had caused damage) was healthy, and there was no appreciable leaf-fall. It was remarkable that on the new wood (up to 28 inches long) all of the 30 leaves were healthy although spray deposit could only be seen on the lowermost twelve or thirteen. Hardly an apple was affected with scab, and russetting of the fruit was not so much in evidence as in the previous year. The largest apples measured 2½ inches in diameter.

On the unsprayed Allington trees, scab was easily seen but apparently it had not been recently spreading. Some of the new wood had attained a length of 33 inches and had thirty-two leaves of which as many as thirteen on the upper part of the shoots were healthy. The remaining nineteen, however, on the lower part of the shoot were attacked. This number roughly corresponds to the number found infected two months previously and it would seem that the dry weather played some part in reducing the intensity of the attack. In spite of this, however, practically every apple on these trees was scabbed.

The sprayed Newton trees in the plots A and B were of healthy appearance and the small amount of scab found was dried up and not actively sporing ; on a few of the youngest leaves, however, when it occurred, it was powdery with spores and olivaceous. The longest of the new wood measured 25 inches and bore twenty-six leaves of which as many as eighteen were unsprayed or showed no trace of spray deposit. Occasionally all the newer unsprayed leaves were found attacked, though more commonly only the lowermost (immediately above those protected by Bordeaux deposit) were infected. On these the fungus was usually dried-up and appeared inactive. It was only rarely that apples (now 2¼ inches diameter) could be found spotted with scab. There was no appreciable leaf-fall.

The majority of the foliage on the unsprayed (control) Newtons was infected with scab. From the new wood (up to 25 inches long), many of the lower leaves had already fallen, leaving only a tuft of leaves at the tips of breastwood and leaders.* Even the youngest leaves at the tip were attacked. There was very little fruit, and scab occurred on nearly every apple.

In contrast to the previous year, the total crop in 1928 was a light one ; the Allingtons gave 14½ cwt. (against 4 tons 2 cwt. in 1927) and the Newtons, 1 ton 12 cwt. (against 4 tons 7¾ cwt. in 1927). The crop was picked on October 8th-10th and was graded by hand, exactly the same method of grading being followed as in 1927 ; Grade 1 consisted of apples free from scab† ; Grade 2 of apples on which scab spots were few or many but the fruit was not unmarketable ; Grade 3 of apples so cracked or disfigured by scab as to be unmarketable.

In 1928 the amount of scab on the unsprayed (control) trees was very considerable, although slightly less than in 1927. The Allingtons gave 82 per cent. by weight of scabbed apples (against 93 per cent. in 1927) viz. 77 per cent. in Grade 2 and 5 per cent. in Grade 3 whilst 18 per cent. of the crop was scab-free (Grade 1).

* A bad attack of " Red Spider " doubtless assisted in this damage.

† As many as three very minute spots on an apple (each not larger than the head of a pin) were not considered sufficient to reduce that fruit to the level of Grade 2. Such cases were numerically very small.

TABLE 1.

Plot and Treatment.	Variety.	No. of trees.	No. of apples picked.	Percentage No. of apples in grade			Weight of apples lb.	Percentage Weight of apples in grade		
				1	2	3		1	2	3
A. Hydrated lime Bordeaux	Allington	12	2,015	89	11	0	632	88	12	0
	Newton	12	5,226	85	15	0	1,429	86	14	0
B. Quicklime Bordeaux	Allington	12	2,030	88	12	0	600	88	12	0
	Newton	15	5,504	82	18	0	1,456	83	17	0
1. Control (unsprayed)	Allington	3	203	10	75	15	54	11	82	7
	Newton	6	823	13	80	7	182	15	81	4
2. Control (unsprayed)	Allington	3	418	14	79	7	113	15	81	4
	Newton	6	1,174	14	80	6	263	15	81	4
3. Control (unsprayed)	Allington	6	1,056	17	73	0	240	20	75	5
	Newton	3	1,155	18	77	5	252	20	76	4
Controls together (unsprayed)	Allington	12	1,677	15	75	10	407	18	77	5
	Newton	15	3,152	15	79	6	697	17	79	4

The Allingtons sprayed with either type of Bordeaux mixture gave by a curious coincidence the same percentage weight of scab-free apples as in 1927, viz. 88 per cent., the remaining 12 per cent. being in Grade 2.

The Newtons in the three unsprayed (control) plots taken together, yielded 83 per cent. by weight of scabbed apples (against 86 per cent. in 1927), viz. 79 per cent. in Grade 2, and 4 per cent. in Grade 3, while 17 per cent. of the crop was scab-free (Grade 1).

The Newtons sprayed with hydrated lime Bordeaux mixture gave 86 per cent. of scab-free apples (88 per cent. in 1927) and with quicklime Bordeaux mixture 83 per cent. scab-free apples (against 86 per cent. in 1927) and in neither case were there any Grade 3 apples. The above figures show that a very satisfactory control of scab was obtained by spraying three times with Bordeaux mixture.

As in 1927, a record was kept of all apples showing distinct russetting ; the results in 1928 are given in Table 2.

TABLE 2.

Plot.	Variety.	Number of apples.	Weight of apples (lb.).	Percentage russetted (by number).	Percentage russetted (by weight).
A.	Allington	72	19	3·5	3·1
	Newton	6	2	0.11	0.14
B.	Allington	85	22	4.2	3.7
	Newton	14	4	0.25	0.28

It will be seen that, as in 1927, Allington Pippin is more subject to russetting with both types of Bordeaux mixture, than is Newton Wonder. There is a very close agreement with the figures obtained in 1927 when the Allingtons showed russetting to the extent of about 3 per cent., and Newtons from 0.6 to 0.2 per cent. In both years and with both varieties, the injury may be regarded as negligible. The absence of any serious injury due to " scorching " is probably to be attributed to the fact that drenching of the foliage was carefully avoided.

Discussion.

One of the reasons for a repetition of the experiment was to find out whether the very successful results in the control of scab obtained in 1927 were to be regarded as exceptional, and due to special climatic or other conditions. The almost identical results obtained in 1928 show that this is not so and the contention that growers can satisfactorily control scab on Allington Pippin and Newton Wonder by the use of Bordeaux mixture receives very strong support. The seasons of 1927 and of 1928 differed markedly as regards weather ; the former year was characterised by a very wet summer whilst the latter was wet and cold in the spring and warm and very dry in the summer.

It is also of interest to have confirmation of the fact that Bordeaux mixture prepared with hydrated lime is equal in efficiency to that made in the ordinary way with quick lime. By the use of hydrated lime which can be kept on hand and which does not deteriorate for at least several months if packed in paper-lined bags, and a stock solution of copper sulphate, which can be prepared beforehand and kept for any length of time, the making of Bordeaux mixture becomes a very simple operation.

Summary.

1. Similar plots of trees of Allington Pippin and Newton Wonder were sprayed three times with two types of Bordeaux mixture, made respectively with hydrated lime and quick lime. The fungicidal powers of the two mixtures proved, as in 1927 in similar experiments, to be identical and eminently satisfactory.

2. In the control plots, the percentage by weight of scab-affected apples was 82 in the Allington Pippin and 83 in the Newton Wonder. In the sprayed plots, the percentage by weight of scab-affected apples was Allington Pippin, 12 ; Newton Wonder, 14 and 17.

3. No appreciable leaf-scorch was caused on either variety by the spraying. Russetting of the fruit occurred to a slight extent, but was appreciable in only 3.1 to 3.7 per cent. of the Allington and 0.14 to 0.28 per cent. of the Newton variety.

II.—WORCESTER PEARMAIN.

In 1927 and 1928 spraying experiments were carried out in an apple plantation near Canterbury, belonging to Mr. S. W. Mount, to whom we are much indebted for supplying all the necessary facilities.

The plantation consisted of 688 half-standard trees with 2 foot stems, about twenty-four years old, planted at 16 feet square. The height of the trees was 10-15 feet, and their spread 10-12 feet. Two control plots, 1 and 2, of forty and thirty trees, at each end

of the plantation, were left unsprayed. The remainder of the plantation was divided, leaving " guard-rows," into four plots which were sprayed as follows: A, sixty-eight trees, Bordeaux mixture applied three times; C, seventy trees, Bordeaux mixture twice; B, sixty-six trees, Bordeaux paste* three times; D, seventy trees, Bordeaux paste twice. The strength of the Bordeaux mixture, which was prepared in the usual way, was 8 lbs. copper sulphate, 8 lbs. quick lime, 100 gals. water. The Bordeaux paste was used at the strength of 8 lbs. to the 100 gals. of water.

The mixing tubs were situated on a road at the side of the plantation and the liquid was pumped from these by means of a 6 h.p. Lister engine at about 300 lbs. pressure, through overland (Merryweather) pipes to the different plots. Lengths of rubber hose (120 feet) were attached to different stop-cocks and four men using short Myer's spray guns were thus enabled to spray simultaneously. All pipes and guns were washed out with water before the commencement of spraying each plot.

The programme of spraying and field notes respecting the incidence of disease on each plot are given below for the two seasons.

1927. The sprays were applied on May 3rd, May 20th, and June 10th. In the first spraying, Plot A received about $\frac{5}{7}$ gal. to the tree, and Plot B about $\frac{6}{7}$ gal.; in the second spraying, plots A and C received about $1\frac{1}{4}$ gal. and plots B and D $\frac{6}{7}$ gal. per tree; in the third spraying, plots A and C received $\frac{4}{7}$ gal. per tree, and plots B and D $1\frac{1}{4}$ gal.

The first spraying at the " pink bud " stage was on May 3rd in fine sunny weather with a slight breeze. Plot B (Bordeaux paste three times) which was found to be entirely free from scab, was sprayed first. The volume of spray and the breeze were such that a cloud of mist was carried for a distance of 21 yards from the sprayers and in this way there was a slight drift into the adjoining plots A and 1. Plot A (Bordeaux mixture three times) was sprayed next; this plot was noticeably more forward than the last, there being more blossom and more leaves surrounding the trusses. Scab was not present here and in the whole plantation it was very scarce, only two affected leaves being found.

On May 20th (seventeen days later) the next spraying took place in still, sunny weather. In B some complete trusses were still in full bloom and the tops of many trees were white with blossom. No scab was found—probably owing to the continued dry weather. In plot D (Bordeaux paste twice) some of the trees were nearly out of flower while others still showed a considerable quantity of blossom. The late flowering was accounted for at the time by the prevalence of frosty conditions at night. No scab was found in this plot. In A, no scab occurred. In plot C (Bordeaux mixture twice) and in the control plots 1 and 2 there was no disease.

On June 10th (twenty-one days later) the third spraying was carried out in sunny weather with only a slight breeze. At this date there was considerably more foliage and the largest apples had reached a diameter of $\frac{5}{8}$ inch. Scab was absent from all plots except control plot 2 in which one spot only was found on one leaf.

On July 7th (twenty-seven days after the third spraying) the plantation was again inspected. In plot D only one leaf was found infected and this was black with scab over the entire upper surface. A few apples in plot B were already scabbed but only one leaf was found affected. In plot C a few of the apples were russetted†; this

* The proprietary paste used was Bordorite.

† Russetting and cracking of unsprayed Worcester Pearmain apples was observed in this and another plantation, several miles away, in 1926 also.

injury to the fruit could not be attributed to the spray because it occurred in the control plots where it was also accompanied by cracking. A few of the young apples were spotted with scab but only one leaf was found attacked. The slight injury described was present also in plot A ; here there was even a greater scarcity of disease and only one apple was seen affected. Plot 1 was fairly free from disease ; hardly an apple was scabbed and only a few leaves were affected. Plot 2 showed signs of an attack developing ; scab was starting on several leaves and there were small spots on a few of the apples. At this date the fruit had reached a diameter of 1½ inches.

From the above observations it is clear that, probably owing to the dry weather, scab was unable to make any general attack on the trees until well into June. Under these special seasonal conditions (which perhaps are to be considered as exceptional in our climate) it would appear that in 1927 spraying in May at the " pink bud " stage was unnecessary in this plantation.

1928. The sprays were applied on May 2nd, May 24th and June 19th. In the first spraying, plots A and B both received about $\frac{6}{7}$ gal. per tree ; in the second spraying, plots A and C received 1⅛ gal. per tree and B and D 1⅙ gal. ; in the third spraying all the plots received about 1 gal. per tree.

On May 1st the first spraying was carried out under ideal conditions in weak diffused sunshine with dull grey clouds and with only a very slight breeze. There was promise of abundance of blossom and the trees were in the advanced " pink bud " stage with here and there one flower open in the truss.

In plot B, which was sprayed first, scab was not infrequently present on the small leaves surrounding the blossom trusses. Usually there was a single scab spot on the leaf, either on the upper or lower surface, and it had been established long enough to cause a brown mark to appear on the surface opposite to the one on which the scab was present. Not every leaf of the whorl of six was attacked but usually two or three. On a few of the trees in this plot, some of the trusses consisted entirely of open blossoms. Plot A was next sprayed with home-made Bordeaux mixture. Here also the scab attack had already begun but fewer spots of infection were found.

In the two control plots (1 and 2) and in plots C and D (which were not sprayed at this date) the attack had started but not so such an extent as in plot B.* In plot D there was more scab at the end adjoining B. The spots of scab measured as much as 1.0 cm. in diameter and the brown, killed areas corresponding to these, measured from 1.0 to 5.0 mm. Puckering of the leaves occurred when the fungus was present near the margin.

On May 24th (twenty-three days later) the second spraying was given. The weather was cloudy, dull and still ; rain had fallen during the morning but the foliage had dried before spraying began. The trees were covered with trusses which had now set and which were subtended by a whorl of about seven small leaves and sometimes with a wood bud arising at the side. In plot D spots of scab occurred on these leaves and on those surrounding the next years fruit buds (*lambourdes*). New wood was scarce and the buds had not elongated more than 2 inches (5.1 cm) with eight to ten leaves expanded. These were all healthy. The scab attack was threatening but had not yet reached serious proportions.

* Separated from plots 1, B and D by a farm road, were blocks of the varieties Millers Seedling, Lane's Prince Albert, and Beauty of Bath. All of these were infected with scab, the Beauty of Bath opposite plot D being the worst attacked.

In plot B the disease was scarce but was present here and there on some of the young leaves, as for example those on the scarcely elongated new wood—a fact which showed that the attack had developed during the past three weeks. These leaves were in the arrangement of a rosette with one longitudinally folded leaf in the centre. Occasional spots of scab were found on leaves surrounding the trusses and which probably missed the first spray. There was less scab here than in plot D.

Plot A was next sprayed. Scab was very rare but sometimes it covered the entire surface of a leaf of a shoot or of a *lambourde*. It was evident that the disease had had time to become established before the weather permitted the second spraying. In plot C more disease was present than in A although it was not bad ; it occurred on a few of the oldest leaves around the trusses, sometimes covering the whole surface or only spotting the younger leaves of wood buds or of *lambourdes*. The control plots 1 and 2 contained only a few spots of scab occasionally on the leaves of a wood bud, rarely on the old leaves around the trusses, and the disease (especially in plot 1) was scarce.

On June 19th (twenty-six days later) the third spraying was given in dull, grey weather with a gentle and cold breeze. In plot B the newer* leaves were commonly sooty with scab along the veins on the upper surface. Spots of scab (3 mm. diameter) occurred on the fruit which was not by any means plentiful. The progress of the disease was evident on a very few wood buds which had elongated and had reached a maximum length of 6 inches with thirteen leaves. In typical examples, six leaves were sprayed and killed scab spots were visible on them. The seventh leaf was covered with scab and the eighth to thirteenth were healthy. The apples had reached a diameter of $\frac{7}{8}$ inch. In plot D the condition of the trees and intensity of disease was exactly similar. Large numbers of leaves with purple-brown irregular spots of killed scab were present in plot C where the apples were commonly infected—the spots of scab sometimes joining to cover the whole of one side. The newer, unsprayed leaves around the next year's fruit buds were often scabby over the whole surface and spotted below. New wood was very scarce but a few shoots had reached 8 inches in length with 14 leaves expanded. Nine of these were already sprayed, the ninth commonly showing reddish or purplish dead patches of scab and the tenth was nearly covered with living scab spots. The eleventh to fourteenth were not affected The foliage of the trees very generally showed the irregular reddish patches of dead scab. It was apparent that the disease had been effectively checked but the fruit had nevertheless become infected.

In plot A many apples were scabbed and the various features noted in plot C were found here also. In control plots 1 and 2 the whole surface of many of the newer leaves was covered with scab. The older leaves were not much affected. Whereas on May 24th, on the previous inspection of these plots, the scab was scarce, it was now common and also attacking the apples themselves ; it was evident that infections must have occurred to a great extent during the twenty-six days intervening. The condition of the foliage on the new wood tended to confirm this view ; on shoots 4 inches long, scab occurred only on the eighth, ninth and tenth of the thirteen leaves (counting from the base).

A light rain fell about half-an-hour after the spraying was completed but not in sufficient amount to wash away the spray deposit.

* There was hardly any growth of wood and the leaves referred to as " newer " were the two fresh leaves most recently unfolded in the rosette around next year's fruit buds (*lambourdes*).

On August 27th all the plots were again examined when the fruit had attained a diameter of up to 2 inches. It was found that about one-quarter of the apples had fallen to the ground both in the sprayed and unsprayed plots.

In plot D there was a light crop and the greater part was scabbed. The foliage was much cleaner than in the neighbouring control plot 2 where the apples were also more heavily infected. In this control plot most of the leaves were diseased and on the rare new shoots (up to 14 inches long) even the youngest of the nineteen leaves was attacked. In plot B the majority of the fruit was scabbed; the foliage was more plentiful and somewhat cleaner than in D. The foliage in the adjoining plot 1 was also plentiful but was more infected with scab. The fruit was nearly all infected. In plot A most of the apples were scabbed and there was also a trace of russetting on a very few. The disease occurred to about the same extent on the crop in plot C, and here the foliage was as clean as in plot A.

The field notes given above show that the incidence of scab under the seasonal conditions of 1928 was very different from that in 1927. By May 1st, the date of the first spraying, the fungus had already attacked the trees to a serious extent. It is probable that this early and general infestation (caused presumably by winter-spores (ascospores) coming from dead leaves on the ground) accounts for the lack of proper scab-control during the season. While in 1927 the pre-blossom application might have been dispensed with, it appears probable that in 1928 an early spraying at a stage when the leaf buds were just unfolding and while the blossom buds were still unexpanded in the truss was necessary in order to prevent the infection which was found to have taken place by May 1st. This early infestation also explains why the plots receiving three applications of Bordeaux mixture gave practically no better results than those receiving only two. With respect to the two seasons, it appears that in 1927 spraying at the "pink bud" stage produced no effect owing to the absence of the fungus during May, while in the same month in 1928 there was already too much infection.

Discussion of Results.

The total crop (6 tons 7 cwts. 20 lbs. in 1927 and 1 ton 11 cwt. 25 lbs. in 1928) was graded by hand for scab. The results are shown in Table 1. The control of scab was very different in the two seasons, being moderately good in 1927 and very poor in 1928. It is obviously a matter of considerable interest to try to discover the possible reasons for this difference. In the season of 1927 the two applications of Bordeaux mixture resulted in 61 per cent. (by number) of the crop being quite free from scab, while in the two control plots the percentage was only 39 and 22. In the plot in which Bordeaux mixture was applied three times the percentage of scab-free apples was 55.4, i.e., slightly lower than where only two sprayings had been given. Similar results were obtained as between the plots sprayed twice and three times with Bordeaux paste. One explanation might be that the incidence of scab was greater in the plots where three applications were made, rather than that the differences lie within the experimental error.

If the pairs of sprayed plots are considered as single units (C + A and D + B) 58 per cent. healthy apples are obtained as the result of spraying with Bordeaux mixture, 26 per cent. from spraying with Bordeaux paste, while the unsprayed plots, taken together, had 28 per cent clean. It is clear that in this season the results of spraying with home-made Bordeaux mixture were nearly to double the percentage of scab-free fruit, while, under the conditions of the experiment, the use of Bordeaux paste appeared to give no control of scab.

TABLE I.

BARTON FARM, CANTERBURY.—*Variety, Worcester Pearmain. Results of spraying two and three times with Bordeaux mixture and with Bordeaux paste.*

Plot.	Spray-fluid.	Number of apples picked.	Percentage number of apples in Grades*			Weight of apples picked. (lbs.)	Percentage weight of apples in Grades*		
			1	2	3		1	2	3
1927									
C.	Bordeaux mixture (applied twice) ..	12,988	61.3	38.3	0.4	2,413	61.2	38.5	0.3
A.	Bordeaux mixture (applied three times) ..	16,653	55.4	44.1	0.5	2,951	55.4	44.2	0.4
D.	Bordeaux paste (applied twice)	16,749	28.9	69.4	1.7	2,728	29.0	69.7	1.3
B.	Bordeaux paste (applied three times) ..	17,039	23.6	74.1	2.3	2,968	24.4	73.9	1.7
1.	Control (no spray)	12,924	22.1	75.7	2.2	2,136	23.3	75.2	1.5
2.	Control (no spray)	6,648	38.5	60.8	0.7	1,048	38.1	61.4	0.5
1928									
C.	Bordeaux mixture (applied twice) ..	8,151	2.7	50.1	47.2	896	3.5	57.2	39.3
A.	Bordeaux mixture (applied three times) ..	5,277	2.8	53.9	43.3	620	3.9	59.8	36.3
D.	Bordeaux paste (applied twice) ..	5,139	0.2	45.5	54.3	558	0.4	53.2	46.4
B.	Bordeaux paste (applied three times) ..	5,670	—	34.3	65.7	616	—	41.7	58.3
1.	Control (no spray)	3,258	0.1	34.3	65.6	356	—	42.4	57.6
2.	Control (no spray)	4,314	0.1	41.0	58.9	451	0.2	48.3	51.5

* The system of grading adopted was as follows: Grade 1 consisted of apples free from scab; Grade 2, of those apples on which scab spots were few or many, but which were not unmarketable; Grade 3, of apples which were so cracked or disfigured by scab as to be unmarketable.

In the season of 1928 the incidence of scab was far more severe than in 1927. A comparative failure to control the disease by spraying resulted, and a very high percentage of apples was obtained in Grade 3—cracked and disfigured by scab to the extent that they were unmarketable. In the control plots (taken together) the percentage of Grade 3 was 62; in the paste plots 60, and in the Bordeaux plots 46. The results of the spraying as regards clean fruit were as follows: two applications of Bordeaux mixture resulted in only 2.7 per cent. of the crop being scab-free, while with three applications the percentage was only 2.8—no real increase; two applications of the paste gave 0.2 per cent. healthy, while three gave no healthy apples at all; both control plots gave 0.1 per cent. healthy apples.

It is very doubtful whether, under the conditions of 1928, spraying with the paste gave any control whatever of the scab. Taking plots D and B together, the slightly higher percentage (40) of the apples in Grade 2 over that (38) in the two controls together, is probably a difference well within the experimental error. In plots C and A, the proportions (although very small) of the crop in Grade 1 and the reduced percentage in Grade 3 shows again in 1928 the superiority of home-made Bordeaux mixture over the paste.

It remains now to discuss the possible reasons for the failure in 1928 to control the disease. It is to be noted first that in 1927 the control was by no means perfect, since on the two plots sprayed with Bordeaux mixture 42 per cent. of the crop was scabbed. In other spraying experiments a very satisfactory control was obtained by the use of home-made Bordeaux mixture for two seasons on the varieties Newton Wonder and Allington Pippin; in 1927 three sprayings resulted in from 86 to 88 per cent. of the crop being scab-free, while the control plots gave only 14 per cent. of clean fruit in the Newton Wonder and 7 per cent. in the Allington Pippin. In 1928 (as recorded above, p. 34), the same treatment resulted in from 83 to 88 per cent. of scab-free apples, while in the control plots only 17 to 18 per cent. were healthy. The chief differences between the two sets of experiments are in the variety of apple, the cultivation, and the method of spraying. As regards variety, it is possible that Worcester Pearmain is constitutionally more susceptible to scab than Allington Pippin or Newton Wonder, but if so, this fact alone cannot be considered to give the full explanation. With regard to cultivation, the trees of Allington Pippin and Newton Wonder were grown in a plantation kept clean by digging and hoeing, while the Worcester Pearmain trees were in ground which had been allowed to become more or less grassed over, pigs (unfolded) were run over the ground in 1927, but not in 1928. Scabbed leaves of the previous season were always to be found entangled in the grass under the trees and it was observed both in 1927 and in 1928 that these leaves bore ripe fruit-bodies (*perithecia*) of the scab fungus which were ejecting winter-spores (*ascospores*) at the time when the spraying operations were carried out. There is no doubt that a potent and prolific source of infection existed in these dead leaves on the ground throughout the spring and summer months. The work of mycologists in the United States has shown that winter-spores are discharged in enormous numbers from the dead leaves of the previous season. In certain experiments the air in orchards at 18 inches from the ground was drawn through a filter and the number of winter-spores obtained was computed from counts made under the microscope. On one rainy day in May winter-spores were caught throughout a five-hour period at the average rate of 289 per cubic foot of air; this was at the time when the fruit buds were at the "green-tip" stage. Early observations showed that infection of the sepals frequently took place and that secondary infections follow by means of water-carried summer-spores. The greater part of the season's discharge of the winter-spores from the dead leaves may occur before the blooming period of the tree.*

Recent investigations show clearly that the number of sprayings before blossoming-time which are necessary for the control of scab varies under different conditions and in different districts. Thus in the United States, Wallace† inclines to the view that one application, in the "pink-bud" stage, is sufficient, while Keitt and Jones (l.c.) and other investigators state that under severe epidemic conditions as many as three applications may be necessary before blossoming-time; viz., (1) at the "green tip" or "mouse ear" stage; (2) at the "closed cluster" stage; and (3) at the "open cluster" or "pink bud" stage. In Canada, two applications are recommended—the first in the "green tip" stage and the second in the "pink bud" stage.§ In this country experimental work is urgently needed to ascertain whether the failure to control scab satisfactorily

* An excellent study of the epidemiology and control of apple scab is given by C. W. Keitt and L. K. Jones in Research Bull. 73, Dec., 1926, of the Agric. Exper. Station of the University of Wisconsin, Madison, U.S.A. A survey of the literature is also given here.

† Agric. Exper. Station of the Cornell University, Bull. 335 (1913).

§ Apple Scab, by J. F. Hockey (Dominion of Canada, Department of Agriculture, Pamph. 82 (1927).

may not be due to the neglect to spray sufficiently early. Our experiments have shown that under certain conditions in this country, e.g., in a cleanly cultivated plantation of mixed Allington Pippin and Newton Wonder trees, one spraying of home-made Bordeaux mixture at the " pink bud " stage followed by two later applications effectively controlled scab. It is possible, however, that in the case of orchards or grassed-over plantations, where undoubtedly a greater source of infection in the spring exists in the dead leaves entangled in the grass under the trees, more than one application before blossoming time will be found necessary.

With respect to methods of spraying, in the Allington Pippin plantation 6 ft. spraying rods were used with " Mistifier Junior " nozzles fitted with the smallest aperture discs, and a hand machine maintaining a pressure of 70-125 lbs. In spraying the Worcester Pearmain trees spray guns were used and a pressure of about 300 lbs. was supplied by an engine of 6 h.p. In comparing the two methods it is obvious that greater individual attention is given to the tree by the sprayer using the rod, who is able to direct the spray to the branches one after the other until the whole tree is wetted while with the spray gun, owing to the greater volume of spray produced, the tree as a whole is sprayed, resulting almost necessarily in some of the branches receiving little or no spray. The spray gun when in perfect working order can be regulated to give a fine mist-like spray and the sprayer can then (if there is not too much wind) walk round the tree and attend to the spraying of different parts of it ; frequently, however, a slightly coarser spray is used, owing to the spray gun not being in perfect order, and it is then only possible for the sprayer to direct the volume of spray very rapidly *en masse* on to the tree, as any attempt to spray separate parts of it would result in the drenching of the tree. Such over-spraying was carefully avoided in the experiments, for fear of producing scorching injury on leaves or fruit, and it is possible that an insufficient amount of spray was applied.

In the writers' opinion, however, the main reason for the lack of control of the scab in 1928 was undoubtedly the prolific source of infection (presumably in the form of winter-spores on dead leaves) present in the orchard, which led to a general occurrence of the disease on the young opening leaves before the first spraying had been given, and which doubtless continued during rainy periods for many weeks.

SUMMARY.

1. In 1927 and 1928, plots of Worcester Pearmain trees were sprayed two and three times respectively with home-made Bordeaux mixture or Bordeaux paste (Bordorite).

2. In 1927 the percentage of scab-free apples in the Bordeaux mixture plots was 61 and 55 ; in the Bordeaux paste plots 29 and 24 ; and in the control (unsprayed) plots 39 and 22.

3. In 1928 the percentages of scab-free apples in the respective plots were 3 (both plots), 0 (both plots), 0 (both plots).

4. Three applications, including the early spraying at the " pink bud " stage, did not in either year secure a better control of scab than two applications. It was noted that in 1927 no early infection of the opening leaves took place, whereas in 1928 a general infection of the opening leaves had already occurred before the date of the first spraying.

5. The failure to control the disease in 1928 is attributed to early and continued infections by winter-spores arising from the dead leaves of the previous season.

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